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150

APPLICATIONS OF AERIAL INFRARED IMAGERY TO RESEARCH ON THE DUTCH ELM DISEASE

with specific reference to urban areas

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APPLICATIONS OF AERIAL INFRA-RED IMAGERY TO RESEARCH ON THE DUTCH ELM DISEASE WITH SPECIFIC REFERENCE TO URBAN AREAS

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INTRODUCTION

Some of the more memorable American cities have many of their streets lined with stately elms. Denver, Colorado, is one such city. In many northeastern and midwestern cities the inhabitants have witnessed what the results can be if the so-called Dutch Elm disease is allowed to run its course.

This bibliography grew out of a research effort designed to formulate a program of control relative to the disease, with early detection, removal and destruction of the affected trees as key elements. Research efforts were on the use of infra-red photography as a means of detecting stress in plants. This bibliography is offered in the belief that municipal officials may find the sources of value in attempting to effect a program of controlled attrition for warding off the effects of the Dutch Elm disease.

CONTENTS

I. TREES, TREE PATHOLOGY, AND DUTCH ELM DISEASE

AGRIOS, G.N. Plant Pathology. New York: Academic Press, 1969.

Includes a general classification of plant diseases, effects of plant nutrition, the role of environmental factors in plant diseases and control of plant diseases: has relatively recent and relevant information on Dutch Elm Disease.

AL-AZAWI, A.F. & NORRIS, D.M. Experimental Prevention of Bark Beetle Transmission of Ceratocystis ulmi (Buis.) Moreau with the Systematic Insecticide Chipmen R-6199. Journal of Economic Entomology, 1959, 52, 902-904.

Detailed report of experiments showing that some insecticides may be useful in reduction or prevention of transmission of Dutch Elm Disease by the beetles. Trunk implantation of insecticide Chipmen R-6199 proved successful.

BAKER, J.E.; RAINEY, F.P.; NORRIS, D.M. & STRONG, F.M. p-Hydroxybenzaldehyde and Other Phenolics as Feeding Stimulants for the Smaller European Bark Beetle. Forest Science, 1968, 14, 91-95.

Reports on experiments showing that certain components of the elm bark chemical make-up stimulates the bark beetle's feeding. Quite detailed but may develop into important studies in terms of controlling or destroying the beetle.

BANFIELD, W.M. Dutch Elm Disease Recussence and Recovery in the American Elm. Pytopathologische Zeitschrift, 62, 21-60.

Excellent source of information covering exactly what title suggests: extremely thorough source.

BANFIELD, W.M. Distribution of the Sap Stream of Spores of Three Fungi that Induce Vascular Wilt Disease of Elm. Journal of Agriculture Research, 1941, 62, 637-681.

Movement is much further and more rapid during the growth than during the dormant period. There is also much more movement from the trunk and limbs than from terminal twigs. Rapid invasion of C. Ulmi during the leafy season of the bole and crown of American Elm is due to the distribution of the spores of these fungi of the large vessels of the new annual ring by the sap stream.

BOYCE, J.S. Forest Pathology. New York: McGraw Hill, 1938.

One section of this book discusses the causes and symptoms of Dutch Elm Disease. Book is not up-to-date but offers adequate description.

BROWN, H.D.; KUCERA, D.R. & PEACHER, P.H. Dutch Elm Disease Detected in Alabama. Plant Disease Reporter, 1969, 53, 307.

Reports two occurrences of Dutch Elm Disease in Alabama during 1968. These were the first known cases in that state.

Chemical Helps Fight Dutch Elm Disease. Science News Letter, 1962, 81, 120.

Brief article reviews the effectiveness of a particular chemical (Shell 3562) in control of Dutch Elm Disease. Chemical seemed to be effective but no long-term or large field studies were reported. Chemical is injected into tree trunks rather than sprayed.

Closer to Curing the Elm. Agricultural Research (U.S.D.A.), 1970, 18 (9), 3.

USDA reports some success against Dutch Elm Disease with the fungicide - Benomyl. However, USDA has not registered Benomyl yet for treatment of Dutch Elm Disease.

CLINTON, G.P. & McCORMICK, F.A. Dutch Elm Disease. Connecticut Agriculture Experiment Station, New Haven, Bulletin 389, 701-52.

History of Dutch Elm Disease from first discovery in United States in 1930: discusses early research into disease.

Chemical Retards Spread of Dutch Elm Disease. Science News Letter, 1965, 87, 8.

Control of spread of Dutch Elm Disease can be achieved through chemical treatment with SMDC (Sodium N-menthyl dithiocarbamate), which breaks underground root connections between the trees. Chemical is poured into holes in the ground between trees: estimates are 75 percent of all Dutch Elm Disease transmitted from one tree to another through root connections.

COLLINS, C.W.; BUCHANAN, W.D.; WHITTEN, R.R. & HOFFMAN, C.H. Bark Beetles and Other Possible Insect Vectors of the Dutch Elm Disease. Journal of Economic Entomology, 1936, 29 (1), 169-176.

Describes early history of Dutch Elm Disease and early research conducted on causes and development. Good information about bark beetles, which carry Dutch Elm Disease.

DICKENS, L.E. Outline Speech on Dutch Elm Disease. (Not for publication-personal communication, April, 1970).

Excellent review of Dutch Elm Disease, especially in Colorado: would serve as excellent outline for speech or slide show.

DICKENS, L.E.; FUCHT, J. & BREWER, W. Prevention and Control of Dutch Elm Disease. (Not for publication or news release - personal communication).

Excellent background information on the Dutch Elm Disease.

DICKENS, L.E.; NAGAYOSHI, O. & ANDREWS, S.R. Distribution of Dutch Elm Disease in Colorado, 1969. Plant Disease Reporter, 1970, 54, 266-7.

Discusses the discovery of Dutch Elm Disease in Colorado, especially in Denver. Good article with an illustration of disease locators in Denver.

Dutch Elm Disease. United States Department of Agriculture. Delaware, Ohio: Proceedings of Meeting Held June 29-30, 1967.

Discusses present status of Dutch Elm Disease in the United States, the research that has been conducted and the effectiveness of control procedures.

ELIOT, W.A. Forest Trees of the Pacific Coast. New York: G.P. Putnam's Sons, 1938.

Discusses and illustrates many of the trees common to the Pacific area: an old but useful work.

Embattled Elms. Time, 1963, 81 (19), 46, 51.

Suggests that effective control program must include both sanitation and spraying. Recommends spraying with methoxychlor, which is less harmful than DDT. Recounts battles between those interested in saving trees and those concerned about peril to wildlife, caused by spraying. Suggests spraying with methoxychlor in late fall or early spring when fewer birds are around.

EPSTEIN, A.H. Low Temperature Sprays for Dutch Elm Disease Controls. Plant Disease Reporter, 1969, 53, 304-6.

Reports on efforts to increase the use of sprays during dormant period of the elm (approximately November to April) by lowering their freezing point. Found that methanol depressed the freezing point of emulsions of methoxychlor and water, without significantly affecting the longevity or effectiveness of the spray. Spraying during dormant season is supposed to be important in sanitation efforts.

FELDMAN, A.W.; CAROSELLI, N.E. & HOWARD, F.L. Physiology of Toxin Production by Ceratostemella Ulmi. Phytopathology, 40, 341-54.

There is some evidence to suggest that the polysaccharide may not be produced in diseased trees; or if produced, that it may not be responsible for the wilt symptoms. Furthermore, introduction of a solution of $Ca(OH)_2$ into trees at the onset of wilt symptoms resulted in a cessation of wilting for a period of at least three weeks, while introduction of water into wilting trees generally retarded wilt symptom for only 24-48 hours. In soil application of basic chemicals, it has been possible not only to retard the destruction effects of the disease, but also to increase the effectiveness of both therapeutic and prophylactic chemicals. Evidence to show that the polysaccharide cannot be considered the prime wilt-inducing component of the culture filtrate. No correlation between polysaccharide formulas and wilting.

HASTINGS, A.R. & BEROZA, M. Speech Outline, 1970

Screening tests for chemical deterrants, progress report on tests made to find control for twig-feeding by Scolytusmultistriates Mash.

HOCK, W.K.; ROBERTS, R.R. & WUERTZ, D.E. A Technique for Rapid Standardization of Conidial Suspensions of Ceratocystis Ulmi. Plant Disease Reporter, 1969, 53, 640-41.

Technical report dealing with standardization of the spores involved in Dutch Elm Disease.

Infra-red Magic. Agriculture Research, 1969, 18 (1), 8-11.

Future NASA space satellite should hasten application of remote sensing techniques to the management of agriculture and other natural resources. Agricultural remote sensing involves determining the part of the spectrum where differences in vegetation, soil or water can be detected, identifying "spectral signatures of contrasting objects or condition and devising computerized techniques for interpreting and processing data obtained by remote sensing and for furnishing the information in photograph, computer print-out, or statistical table."

Interplant to Control Dutch Elm Disease. American City, 1968, 83 (4), 12.

Recommends interplanting other varieties of trees (e.g. hard maple, oak, hackberry, honeylocust, linden and ash) among elms in order to help control or prevent the spread of Dutch Elm Disease and eventually replace any limbs lost.

LAUT, J.B.; NAGAYOSHI, O. & DICKENS, L.E. The Recurrence of Dutch Elm Disease in Colorado. Plant Disease Reporter, 1969, 53, 253.

Twenty years after its first discovery in Colorado, Dutch Elm Disease returned in 1968, being discovered in Fort Morgan, 70 miles northeast of Denver.

MATTOON, H.G. Can Dutch Elm Disease be Controlled. Horticulture, 1963, 41, 274-75.

Reports on studies by the U.S.D.A. Shade Tree and Ornamental Plants Laboratory of three chemical compounds for preventing Dutch Elm Disease: zinc chloride, Tree Saver and Soil Life. None were effective. Conclusion: no known cure or prevention, strongly recommends sanitation efforts.

MAY, C. A New Elm Disease. Science, 1931, 74, 437.

Very early report on discovery of Dutch Elm Disease in Ohio in 1931. One of the first articles on Dutch Elm Disease in America.

MEYER, H.J. & NORRIS, D.M. Dutch Elm Disease Today. Proceedings North Central Branch E.S.A., 1965, 20.

Concise summary of Dutch Elm Disease (e.g. dissemination of Pathogen).

MEYER, H.J. & NORRIS, D.M. Vanillin and Syringaldehyde as Attractants for Scolytusmultistriatur. Annals of the Entomological Society of America, 1967, 60 (4).

This paper reports findings of the chemotactic responses of emerged Scolytusmultistriatus to pure chemicals.

NEELY, D. Dutch Elm Disease Symptom Progression. Plant Disease Reporter, 1970, 54, 127-29.

Reports on research dealing with the spread of the disease and its development within an elm. Suggests there may be "periods" during which the trees are more susceptible.

NORRIS, D.M. Systemic Insecticides in Trees. Annual Review of Entomology, 1967, 12.

Broad review of effectiveness of insecticides in trees.

NORRIS, D.M. A Molecular Structure Requirement for a Systemic Insecticide to be Effective against Elm Bark Beetles in Elm Twigs. University of Wisconsin Forestry Notes, 1964, 116.

This paper summarizes significant findings relating systemic effectiveness against elm bark beetles, to the molecular structure of the chemicals.

NORRIS, D.M. Insecticides for Dutch Elm Disease. American City, 1961, 76 (5), 115-16.

Control of Dutch Elm Disease requires both sanitation and spraying. Recommends spraying with methoxychlor as a 12 percent emulsion spray via a mistblower in the early spring. Methoxychlor compared to DDT: almost as effective, less harmful, not as long lasting and costs more. Both kill elm bark beetle.

Northeastern Forest Experiment Station. Station Paper #156, 1961.

Reports on studies of the deterrent effect of chemicals against Scolytusmultistriatus. Tested 176 chemicals, most were ineffective.

OUELLETTE, G.B. Studies on the Infection Process of Ceratocystis Ulmi in American Elm Trees. Canadian Journal of Botany, 1962, 40, 1567-575.

Good details about Dutch Elm Disease development, which is covered extensively by author.

OUELLETTE, G.B. Morphological Characteristics of Ceratocystis Ulmi in American Elm Trees. Canadian Journal of Botany, 1962, 1463-466.

The fungus produces large numbers of spores as small as 0.5u in diameter in the xylem of American Elms. Fair for details of Dutch Elm Disease development.

Outbreaks of the Dutch Elm Disease in the United States. U.S. Department of Agriculture Circular 322, 1934, 1-19.

Good article written very early about Dutch Elm Disease in the United States. Covers source, distribution, symptoms, cause, development and control aspects.

PARTRIDGE, A.D. & WARD, H.N. Dutch Elm Disease in Idaho - 1968. Plant Disease Reporter, 1969, 53, 140-41.

Reports a great increase in known occurrence of Dutch Elm Disease in Idaho from 1967-68, especially along the Snake River Valley. Discusses spread of the disease and present control efforts, which may be directly applicable to Denver.

PARTRIDGE, A.D. Dutch Elm Disease Found in Idaho. Plant Disease Reporter, 1968, 52, 46.

Reports first discovery of Dutch Elm Disease in Idaho where two trees were infected in Boise.

PEACHER, P.H. & BOWER, C.A. Status of the Dutch Elm Disease in Oklahoma. Plant Disease Reporter, 1969, 53, 768.

Reports on the rapid spread of Dutch Elm Disease through 19 counties since its discovery in that state in 1961.

RANDALL, H.; NAGEL, C.M. & WOOD, L.S. Dutch Elm Disease Found in South Dakota. Plant Disease Reporter, 1968, 52, 349.

Eight American Elm trees were found with Dutch Elm Disease, seven around Sioux Falls and one near the town of Platte. All were "B" strain.

SAYN-WITTGENSTEIN, L. Recognition of Tree Species on Air Photos by Crown Characteristics. Photogrammetric Engineering, 1961, 27 (5), 792-809.

Excellent article dealing with identification of tree species in aerial photographs. Good illustrations, diagrams, and pictures: useful for identification.

SCHREIBER, L.R. & WILSON, C.L. Occurrence of Dutch Elm Disease in North Dakota. Plant Disease Reporter, 1969, 53, 994.

Reports first occurrence of Dutch Elm Disease in North Dakota, discovered in Mandan in August, 1969. Mandan is across the Missouri River from the state capital of Bismark.

SCHREIBER, L.R. Viability of Ceratocystis Ulmi in Young Seedlings of American Elm and the Effects of Extracts from their Tissues in Conidial Germination. Phytopathology, 1970, 60, 31-35.

Discusses development of Dutch Elm Disease in young American Elm Trees. Young trees show some resistance to the disease but this disappears with age. Smalley suggests that susceptibility increases in the period of branch elongation.

SCHUSTER, J.E. & NEELY, D. Rate of Upward Movement of Ceratocystis Ulmi in Elms. Plant Disease Reporter, 1970, 54, 58-9.

Discusses movement of spores in trees.

Shot in the Trunk. Newsweek, 1963, 62, 50.

Recommends control of Dutch Elm Disease through innoculation into tree trunk of compound, Birdin. Innoculation preferred over spraying. Reports 99 percent effectiveness.

SLOANE, R.A. Tree Program Restricts Elm Losses. American City, 1964, 79 (10), 165-66.

Successful control of Dutch Elm Disease reported through combination of sanitation (immediate burning of dead elm wood) and spraying (bi-annually, early spring and summer using DDT and Methoxychlor). Grosse Pointe Park, Michigan reports long-term success with this program.

SMALLEY, E.B. Prevention of Dutch Elm Disease by Treatments with 2,3,6-Trichlorephenyl Acetic Acid. Phytopathology, 1962, 52, 1909-91.

Treatment with this acid helps to prevent or, at least, slow development of the disease. Studies only the one method of treatment.

SMUCKER, S.J. Air Currents as Possible Carriers of Ceratostemella Ulmi. Phytopathology, 1935, 25, 442-43.

Preliminary experiments indicate that spores of C. Ulmi (Schwarz) may be dislodged from mycellium or coremia by air currents. On 5-day culture of C. Ulmi fanned in closed auditorium, 60 plates exposed at various distances were infected. Spores from the old, dry cultures were dislodged less readily than those from fresh young culture. Other experiments indicate that should viable spores lodge in a favorable place, such as a fresh wound in an elm tree, infection may occur.

THOMAS, W.D.; LIST, G.M.; MICHAELSON, M.E. & BUCHANAN, W.D. Dutch Elm Disease in Colorado. Plant Disease Reporter, 1948, 32 (7).

"Dutch Elm Disease has been recently discovered in Colorado (Denver). In the early part of January, 1948, Mr. John Swingle, a Denver tree surgeon, reported evidence of the disease and its carrier, Scolytusmultistriatus. The presence was verified by W.D. Buchanan and samples were sent to the Dutch Elm Disease Laboratory, East Orange, N.J. for verification of presence of Ceratostemella Ulmi in the wood.

On March 12, 1948, presence of the disease was observed by the author, Thomas. The Dutch Elm Disease Laboratory reported isolation of the fungus by them. On April 7-8, 1948, personnel from the Bureau of Entomology and Plant Quarantine, the Colorado Agricultural Experiment Station and Denver Park officials scouted the city of Denver and the surrounding community. Infestation was found in Arvada, Lafayette, Boulder, Longmont and Greeley."

Control attempted with DDT but results not in article. Provides historical value.

Trees. Agricultural Yearbook for 1949. (U.S.D.A.). U.S. Printing Office, Washington, D.C.

An excellent book of articles covering all aspects of trees in the United States. Describes the American Elm and the spread of the Dutch Elm Disease. Useful as an encyclopaedic work on trees in the United States.

WALTER, J.M.; MAY, C. & COLLINS, C.W. Dutch Elm Disease and Its Control. Agriculture Department Circular 677, 1943. (This document has a code of: A1/4.2:677).

Excellent early article discusses the Dutch Elm Disease. Especially good for its time concerning transmission of the disease and sanitation efforts.

WHITTEN, R.R. Elm Disease Sprays, Formulas and Ingredients. Forest Service - Department of Agriculture Bulletin, 1956.

Discusses two spray formulas - one for hydraulic sprayers and one for mistblowers. Formulas are presented along with their ingredients - DDT, Xylol, Emulsifier, Acetone and White Oil.

WHITTEN, R.R. The Dutch Elm Disease and Its Control. U.S.D.A. Information Bulletin, 1958 (revised 1964), 193.

A good summary that includes means of spread, habits of the elm bark beetle, methods of control, spraying and sanitation efforts and plans for developing resistant elms.

WILSON, C.L. Ceratocystis Ulmi in Elm Wood. Phytopathology, 1965, 55, 477.

Discusses development of Dutch Elm fungus, mainly in terms of the Parenchyma Calls of the sap wood rather than in vessels and tracheids. Comparison drawn to similar developments in early stages of oak wilt and persimmon wilt.

WOLFE, R.D. & HATCH, C.L. Dutch Elm Disease Detected in Mississippi. Plant Disease Reporter, 1969, 53, 3.

Reports discovery of Dutch Elm Disease along the Natchez Trace Parkway in Mississippi during June, 1968. First known occurrence in Mississippi. Apparently, many trees are affected.

WOOTEN, J.F. Methoxychlor: Safe and Effective Substitute for DDT in controlling Dutch Elm Disease. U.S. Department of Agriculture Station Notes, 1962, 156.

Fair article on methoxychlor. Suggests that methoxychlor rather than DDT be used to control Dutch Elm Disease.

WORTHLEY, L.H. Progress in Dutch Elm Disease Eradication. Journal of Economic Entomology, 1936, 29 (1), 177-181.

Discusses an eradication program, which took place during the latter part of the depression in the United States, for diseased trees. Poor, very dated study.

WYSON, D.S. & WILLIS, W.G. Recorded Distribution of Dutch Elm Disease West of the Mississippi River as of 1967. Plant Disease Reporter, 1968, 52, 652-53.

Records distribution in many states west of the Mississippi of the disease. Disease is spreading westward. Has a good map of distribution up to the beginning of 1967 (but not through 1967 or beyond). Limited but useful.

II. IMAGERY, IMAGE INTERPRETATION AND RECONNAISSANCE.

Aerial and Orbital Images in Urban Environment Studies. Photographic Applications in Science, Technology and Medicine, 1969, 3 (12), 21-27 (Part I).

Good background of research completed into use of aerial photography in determining and solving urban problems. Covers cameras, film types, etc.

Aerial and Orbital Images in Urban Environment Studies. Photographic Applications in Science, Technology and Medicine, 1969, 3(13), 33-39 (Part II).

Same as for Part I.

Aerial Reconnaissance in Peace and War. NATO'S 15 Nations, 1963.

Thorough discussion of present uses of aerial photography for military and civilian purposes.

ALDRICH, R.C. Forestry Applications of 70mm Color. Photogrammetric Engineering, 1966, 32 (5).

Very good article of work done on photo-interpretation of aerial photographs of forests with 70mm color film. Involves analysis of stress, species identification and inventory.

BAKER, R.D. Aerial Photographs in the Forest. Photogrammetric Engineering, 1967, 33, 1373-376.

Several worthwhile forestry field uses of aerial photographs are: travelling cross country, following bearings and distances to field plots, locating photographic image of occupied ground locations, visualizing recent harvesting changes on outdated photographs and using back of photograph as a source document. The author's recent experience includes enlarging industrial district foresters' use of company photographs. Foresters are encouraged to use aerial photographs in the field and to develop personal procedures for their continued use. Self-help manuals and instructor field experience illustrates how to use photos in everyday work.

BECKING, RUDOLF. Forestry Applications of Aerial Color Photography. Photogrammetric Engineering, 1959, 25, 559-64.

Corrective filters are recommended to reduce color distortion. It is concluded from film-filter experiments that color quality is adversely affected by haze and by increased flying altitude. The most natural color balance is achieved on clear mornings, without a huge filter, flying altitudes of 1,500 to 2,000 feet,

or with a #1-A at flying altitudes of 5,000 feet. Low altitude photography at scales of 1:8,000 to 1:12,000 has the greatest value for intensive management purposes.

BILLINGS, W.E. & MORRIS, R., JR. Reflection of Visible and Infrared Radiation from Trees of Different Ecological Groups. American Journal of Botany, 1951, 38, 327-31.

Compared visible and infrared reflection from different types of trees. Found the greatest reflection in desert species, followed by west-facing pines, north-facing pines and shaded campus-grown varieties. Rather dated report.

BRANCH, M.C. Aerial Photography in Urban Planning and Research. Harvard City Planning Series no. 14. Cambridge: Harvard University Press, 1948.

Simplified explanation of the use of aerial photography for urban planning and the knowledge prerequisite to such use (e.g. flight planning, cameras, film).

BURKS, D.M. & WILSON, R.C. A Vegetation Inventory from Aerial Photographs. Photogrammetric Engineering, 1939, 5 (1), 30-42.

Use of both oblique and vertical views of some timbered area to discover actual ground coverage. Aerial photos (vertical views) shown to be more accurate method of detection.

CARNEGGIE, D.M. & LAUER, D.T. Uses of Multiband Remote Sensing in Forest and Range Inventory. Photogrammetria, 1966, 21 (4), 115-141.

Excellent article that deals with information that can be obtained in the thermal infrared and radar bands of the electromagnetic spectrum in conjunction with conventional aerial photography. Included are panchromatic, black and white near infrared, and active radar imagery.

CARNEGGIE, D.M. & REPPERT, J.N. Large Scale 70mm Aerial Color Photography. Photogrammetric Engineering, 1969, 35 (3), 249-57.

Large scale 70mm color and color infrared aerial photographs of northeast California grasslands and shrublands were evaluated to determine their interpretability for improving range resource inventories. Fair article pertaining to possibility of interpretation of certain aspects of vegetation from aerial photographs.

CANTRELL, J.L. Infrared Geology. Photogrammetric Engineering, 30 (6), 916-41.

Excellent explanation of IR photography which is not extremely technical. However, it applies mainly to geological investigations.

CHISNELL, T.C. & COLE, G.E. Industrial Components - A Photo Interpretation Key on Industry. Photogrammetric Engineering, 1958, 24, 590-602.

Categorization of photo images of industrial components to identify types of industrial activity (e.g. extraction, processing and fabrication industries).

CLESLA, W.M.; BELL, J.C. & CURLIN, J.W. Color Photos and the Southern Pine Beetle. Photogrammetric Engineering, 33 (8), 883-88.

Complete testing of film and data related to relative filters, scale and results. Comprehensive and well-written. This article is a must for any one planning to use color infrared photography for any purpose.

COCHRANE, G.E. False Color Film Fails in Practice. Photogrammetric Engineering, 1968, 34 (11), 1142.

Statement refuted - the film actually offers wide possibilities in forestry studies. Color differences of vegetation seen on Ektachrome Infrared Aero photographs can be seen on normal color photographs of the same vegetation. However, differences are more striking on color infrared because of false color. Published works and studies show that the absence of chlorophyll does not infer green-blue color. Physical and physiological properties of leaves affect spectral reflectance particularly in the infrared region. Wide differences in leaf morphology, between sclerophytic and mesophytic leaves, explain the difference noted in the article. The use of color compensating filters is noted to achieve good color shift. Excellent article on color distribution.

COLWELL, R.N. Some Uses and Limitations of Aerial Color Photography in Agriculture. Photographic Engineering, 1960, 26 (2).

Very good paper on uses of color photography involving aspects of agriculture related to project.

COLWELL, R.N. Some Uses of IR Photography in the Management of Wildland Areas. Photogrammetric Engineering, 1960, 26 (5).

Good paper on background of research, using infrared film applied to forestry, i.e. inventory, species identification.

COLWELL, R.N. Aerial Photography - A Valuable Sensor for the Scientist. American Scientist, 1964, 52, 16-49.

Summarizes the ways, in which aerial photography is currently proving to be a valuable sensor for scientists in many disciplines. Considers the greatly expanded uses for this sensor, which are anticipated for the future. Scope of article is very broad but does summarize many applications of the method to geology, soil

science, forestry, range management, wild life management, agriculture, hydrology, engineering, urban area analysis, disaster analysis, tax assessment, law enforcement, oceanography, meterology, archaelogy, cartography, geography, and military intelligence.

COLWELL, R.N. The Extraction of Data from Aerial Photography by Human and Mechanical Means. Photogrammetria, 1965, 20, 211-28.

Discussion of both human and mechanical limitations in the extraction of data from aerial photos and some insights into their complementary use.

COLWELL, R.N. Color Photos and the Southern Pine Beetle. Photogrammetric Engineering, 1967, 33, 883.

Ektachrome Infrared Aero (type 8443), used in combination with a Wratten No. 12 (minus blue) filter, demonstrated remarkable ability to differentiate between diseased foliage and healthy foliage in certain plants, due to a decrease of infrared reflectivity in diseased leaf tissue, which occurs before disease symptoms are visible to the naked eye. Very good article closely related to Dutch Elm Disease project.

COLWELL, R.N. Remote Sensing of Natural Resources. Scientific American, 1968, 218 (1), 54-69.

Good review of recent remote-sensing applications in detecting natural resources from planes and spacecraft. Methods include utilization of remote-sensing equipment such as radar, gamma ray detectors and sensors of infrared energy.

FAGERHELM, P.O. The Application of Photogrammetry to Land Use Planning. Photogrammetric Engineering, 1959, 25 (4), 523-29.

A discussion of the use of photogrammetry to acquire topographical, land economic and geotechnical information needed in planning the construction of roads, power transmission lines, cities.

FORBES, R.D. Forestry Handbook. New York: Ronald Press, 1955.

An extensive reference work on forestry and related matters. Discusses application of aerial photography to forestry, but this discussion is dated technologically.

FRITZ, N.L. Optimum Methods for Using Infrared Sensitive Color Film, 1967.

This paper is not published but was presented to the 1967 Convention of the American Society of Photogrammetists by the author, associated with the Research Lab of Eastman Kodak Co., Rochester, N.Y. 14650. The abstract of the paper was in December, 1967, issue

of Photogrammetric Engineering and suggested writing to the author for copy of paper. Appears to have good information on techniques of IR photography in determination of stress in trees.

GREEN, N. Aerial Photographic Interpretation and the Social Structure of the City. Photogrammetric Engineering, 1957, 23 (1), 89-96.

This article is premised on the concept of the "urban socio-physical nexus", which recognizes that urban social systems exist in a physical environment and are characterized by material-cultural features, which limit, condition and facilitate social interaction.

HACK, P. (Resident Forester, U.S.D.A.), Evaluating Color, Infrared and Panchromatic Aerial Photos from the Forest Survey of Internal Alaska. Photogrammetric Engineering, 1962, 28 (4).

Vertical aerial photos at a 1:5,000 scale using a 12" focal length camera used with infrared and panchromatic, both with minus blue filter. For identification of tree types, infrared film proved best. Article was poor because it offered no method of determining difference between two film types tested. General material now outdated.

HARRIS, T.H. Use of Aerial Photographs in Forest Protection. Journal of Forestry, 1951, 49, 630-31.

Outlines four steps to be taken by field mapper when mapping and appraising sugar pine to warrant protection against diseases. Rather limited in detail and somewhat outdated.

HEATH, G.R. Correlations between Man's Activities and his Environment which may be Analyzed by Photo Interpretation. Photogrammetric Engineering, 1957, 23, (1).

Poor. Could be used only to describe uses of aerial photography for studies other than forestry.

HELLER, R.C.; ALDRICH, R.A. & BAILEY, W.F. Evaluation of Several Camera Systems for Sampling Forest Insect Damage at Low Altitude. Photogrammetric Engineering, 1959, 25, 137-43.

Large scale color photos can be used to appraise damage caused by several forest insects. An inherent factor with large scale is blurring, which negates the advantages of having a large image. Several camera systems were given limited tests to find a simple and inexpensive way to overcome image-motion. The authors feel that this can be done best by using cameras equipped with extremely fast shutters (1/1,000 second or faster).

HINDLEY, E & SMITH, J.H.G. Spectrophotometric Analysis of Foliage of Some British Columbia Conifers. Photogrammetric Engineering, 1957, 23 (5).

Describes use of aerial photos in identification of tree species of conifers. Good material to be used relating to identification of other tree species.

JENSEN, H.A. & COLWELL, R.N. Panchromatic Versus Infrared Minus-Blue Aerial Photo. Photogrammetric Engineering, 1949, 15 (2), 198.

Early but perhaps most complete study of two types of film. Includes complete breakdown versus tests. Since Panchromatic film not used presently, might be helpful on infrared background information.

JOERG, W.L.G. The Use of Airplane Photography in City Geography. Annals of the Association of American Geographers, 1923, 211.

Paper dealt with that fundamental element in the study of geography, city maps on an adequate scale of 1:15,000, which show built up areas and "the means now afforded by airplane photography to supply that element easily." Of some historical importance, but little applicability today.

LATHAM, J.P. Remote Sensing of the Environment. Geographical Review, 1966, 66 (2), 288-91.

Introduction to the origins and uses of remote sensing techniques, including government involvement, national security problems, on-going seminars and survey of groups engaged in current research.

LAVER, D.T. Multispectral Sensing of Forest Vegetation. Photogrammetric Engineering, 35 (4), 346-54.

The make-up of electromagnetic energy, wave length, wave velocity, etc. Technical terms and applications relating to multiband photography. Excellent article from relatively simple terms to the most complex explanations.

LEONARDO, E.S. (Texas Institute, Inc.). Capabilities and Limits of Remote Sensors. Photogrammetric Engineering, 1964, 30 (6), 1005.

Basic explanation of all various types of remote sensing devices and methods. Good general introduction to field. No specifics but discusses modern camera and infrared film.

LESSE, S.T.B. Photographic Tone in Forest Interpretation. Photogrammetic Engineering, 1951, 17, 785-799.

Fair. Old article which discusses use of tone in photographic interpretation. Covers the many elements that affect tone in photographs.

MEYER, M.P. & FRENCH, D.W. Detection of Diseased Trees. Photogrammetic Engineering, 1967, 33 (9), 1035-1040.

Excellent background and introduction to the use of aerial photography as a practical means of disease detection, for purposes of control programs and as a research tool for following disease development. Discusses the use of steroscopic rather than monoscopic coverage, time of photography, use of color filters to enhance color differences and the use of positive transparencies. For Dutch Elm Disease detection recommends Ektachrome infrared film used at scales of 1:5,000, 1:15,840 and 1:25,000.

MEYER, M.P. & CALPOUZOS, L. Detection of Crop Diseases. Photogrammetic Engineering, 1968, 34, 554-56.

Paper reports on further extension of use of aerial photography in detection of certain disease in field crops including cercospora leaf spot on sugar beets. (Prior studies have been used to detect disease on cereals and potatoes.) Good article for comparative research purposes. Plots of sugar beets, which had been inoculated with Cercospora leaf spot pathogen, were photographed from various flight altitudes with Ektachrome Infrared Aero film in July, August and September of 1966 at Mason City, Iowa. The progress of the disease was clearly discernible, four levels of infection intensity were discernible in the photographs. In addition, a developing epidemic of late flight disease in a southern Minnesota commercial potato field was detected with this film during the same periods.

MORAIN, S.A. & SIMONETT, D.S. K-Band Radar in Vegetation Mapping. Photogrammetric Engineering, 1967, 33 (7), 730-740.

Methods for interpretation of vegetation from radar imagery have been investigated through the use of an image discrimination, enhancement, combination and sampling system (IDECS) developed at the Center for Research in Engineering Science at the University of Kansas. Good description of techniques used to determine differences in vegetation types.

NEWBURT, ROBERT W. Sick Trees. Photogrammetric Engineering, 1969, 35 (5), 472-75.

Study applied to heat sensor detection of root rot disease in Douglas Fir but also could be applied to Elms. Reveals some facts concerning NASA's Natural Resources Program, which finances such studies in an effort to determine feasibility of similar studies through use of satellites. Heat-sensing device that transmits infrared rays to digital computer, which relays material to 2 TV cameras. Excellent and necessary for any research into aspects of IRL photography and stress in trees.

NORTON, C.L. Aerial Cameras for Color. Photogrammetric Engineering, 1968, 34 (1), 36.

In order to produce correctly balanced color and infrared photos, aerial cameras require "distortionless lens having good image quality and fully corrected wide angle lens over angular field. Camera must have a carefully selected automatic exposure control (AEC) so that the exposure latitudes can be met." Lens and AEC requirements discussed and lab tests. Excellent article (technical) covering camera and lens equipment.

O'NEILL, H.T. Keys for Interpreting Vegetation from Air Photographs. Photogrammetric Engineering, 1953, 19 (3), 422-424.

Dated article providing limited information in use of photo interpretation techniques to identify vegetation.

OLSON, C.E. AND GOOD, R.E. Seasonal Changes in Light Reflectance from Forest Vegetation. Photogrammetric Engineering, 1962, 28, 107-114.

Light reflectance from foliage of nine species of trees measured. Hardwood foliage reflected more light than pines in all wave lengths. Light reflected from hardwoods varied erratically by species during fall color change.

PHILPOTTS, L.E. & WALLEN, V.R. Infrared Color for Crop Disease Identification. Photogrammetric Engineering, 1969, 35 (11), 1116-1125.

Various crops in an area can be identified with IR film by their color, characteristic patterns of growth and land uses. They found that scales as small as 1:8,400 are just as effective for this purpose as the larger scale of 1:3,600. They were able to detect bacterial blight and root rot in field beans.

Photo Interpretation in Forest Inventories. Photogrammetric Engineering, 1953, 19 (3).

Basic concept of photo interpretation with infrared to determine tree types. Early methods and brief history with key data relating to methods of interpretation. Dated, but a good basic reference.

POPE, R.B. The Effect of Photo Scale on the Accuracy of Forestry Measurements. Photogrammetric Engineering, 1957, 23(5).

Study completed to determine effect of photo scales of aerial photographs upon reliability of photo interpretation of tree species. Fair.

SCHERZ, J.P.; GRAFF, D.R. & BOYLE, W.C. Photographic Characteristics of Water Pollution. Photogrammetric Engineering, 1969, 35 (1), 38-43.

Special aerial photographs can be used to advantage in detecting and photographing water pollution. For photographing waste from a paper mill discharging into the Wisconsin River, the Kodak film type 8443 with a #4 or a #12 filter proved best with a camera setting of 1/500 sec. at F.-4.5. This is an excellent study of new field techniques with aerial photography.

SPURR, S.H. & BROWN, C.T. Specifications for Aerial Photographs Used in Forest Management, 1946, 12.

Fair study of aerial photography, used for inventory and identification of forests, which could be used as background material.

SPURR, S.H. Photogrammetry and Photo-Interpretation. 2d ed. New York: Ronald Press Co., 1960.
Includes the recognition of vegetation based on tone, texture, shadow pattern, size, shape and dimension. Discusses the importance of tone variations in summer infrared photography used in specie identidication. Lists the crown characteristics of numerous conifers and broad-leaf trees said to be a distinct aid to identification in sharp photos of scale 1:5,000 or less.

SUITS, G.H. The Nature of Infrared Radiation and the Ways to Photograph It. Photogrammetric Engineering, 1960, 26 (5).

Good technical paper dealing with infrared photography what IR radiation is and ways it has been photographed.

TODD, H.N. & ZAKIA, R.D. Photographic Sensitometry, the Study of Tone Reproduction. New York: Morgan & Morgan, 1969.

A comparison of spectral sensitivity of three types of photographic films - black and white panchromatic film, reversal color film and infrared reversal color film - and comments on the use of infrared film in the detection of crop diseases and pollution.

WEISLANDER, A.E. & WILSON, R.C. Classifying Forest and Other Vegetation from Air Photos. Photogrammetric Engineering, 1942, 8 (3).

Excellent paper on classification of tree types from air photographs. Background for determination of tree species.

WILSON, J.E. Sensor Detection: Capabilities Study. Geographic Applications Program U.S. Geological Survey for NASA.

Article relates to remote sensing as to variables, types of sensors and targets for which sensor applicability has been determined. Good technical article.

YOST, E.F. & WENDEROTH, S. Multispectral Color Aerial Photography. Photogrammetric Engineering, 1967, 33, 1020-1033.

Accurate multispectral photography requires the establishment of the spectral reflectance of the ground object. When subtle differences are to be determined, object-to-background spectral reflectivity must be established. A spectophotometer with a diffuse relectance attachment has been used for this purpose. Also discusses improved color separation for the purpose of distinguishing live, dying and dead trees.

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DOVENSPIKE, G.E.; FLYNN, F.M. & HELLER, R.C. Microdensitometer Applied to Land Use Classification. Photogrammetric Engineering, 1965, 31 (2), 294-306.

Discusses application of microdensitometer to land use classification. Not useful to project.

HUDSON, G.D. The Unit Area Method of Land Classification. Annals of the Association of American Geographers, 1936, 26, 99-112.

Includes major problems in geographic field investigation, agricultural land, field materials and procedures. Important for origin of methodology in geography and "land planning".

KAO, R.C. The Uses of Computers in Processing and Analysis of Geographic Information. Geographic Review, 1963, 53, 530-547.

Excellent summary of the use of computer for geographic studies. Covers topics on impact of computers on future geographic research, computers and types of geographic problems such as data reduction, data processing and maps.

MUMBOWER, L.& DONAGHUE. Urban Poverty Study. Photogrammetric Engineering,

1967, 33 (6), 610-18.

Use of aerial photography to obtain socio-economic and demographic information relative to urban environment - in particular, aerial photography used to facilitate the more precise delimiting of poverty areas in cities by the study of physical attributes found to be imaged in the photography.

SIMPSON, R.B. Radar as a Geographic Tool. Annals of the Association of American Geographers, 1966, 56 (1).

Deals with Side Looking Airborne Radar (SLAR). Not valuable to project or any research into IR photography.

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ANDERSON, V.H. High Altitude, Side-Looking Radar Images of Sea Ice in the Arctic. Proceedings of the Fourth Symposium on Remote Sensing of Environment. Ann Arbor: Institute of Science and Technology, University of Michigan, 1966.

AMERICAN SOCIETY OF PHOTOGRAMMETRY. Photo Interpretation in Urban Area Analysis. Manual of Photographic Interpretation. Washington, D.C.: 1960.

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AMERICAN SOCIETY OF PLANNING OFFICIALS. Urban Mapping, Aerial Photography and Duplicating: Some Basic Elements. Planning Advisory Service, Information Report no. 29, 1951.

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BEATTIE, R.K. How the Dutch Elm Disease Reached America. National Shade Tree Conference Proceedings, 1933, 9, 101-105.

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DUKE, R.D. Automatic Data Processing: Its Applications to Urban Planning. East Lansing: Michigan State University, Institute for Community Development and Services, 1961.

ERICSSON, H. Concerning Accuracy in Measuring Tree and Stand Heights. International Archives of Photogrammetry, Proceedings 9th Congress, 1960, 8.

FEDER, A.M. Airborne Multisensing for Reconnaissance and Production. (Paper presented to Tulsa Geological Society, Tulsa, Oklahoma). Tulsa Geological Society Digest, 1965, 33, 286.

GATES, D.M. Physical and Physiological Properties of Plants. Applications of Remote Sensing in Agriculture and Forestry, National Academy of Sciences, 1968.

GOODYEAR AEROSPACE CORP. Image Interpretation Annotated Bibliography. Goodyear Aerospace Corp. Report AAP-20557, 1964.

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HELLER, R.C., et al. The Uses of Multispectral Sensing Techniques to Detect Ponderosa Pine Trees under Stress from Insect or Pathogenic Organisma. Annual Progress Report to the National Aeronautics and Space Administration, 1967.

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JONES, N.E. Bibliography of Remote Sensing of Resources. Earth Resources Survey Program, NASA. U.S. Corps of Engineers: Fort Belvoir, Virginia, 1966.

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V. SPECIAL REFERENCES.

AGRICULTURAL BOARD, NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCE. Remote Sensing, with Special Reference to Agriculture and Forestry. Washington, D.C., 1960.

The most recent and complete work on the use of remote sensing techniques as they apply to agriculture and forestry. Used as a guide to ensure program: covered all aspects of the tool of remote sensing as it is applied to the urban scene and the detection of stress in trees.

NAVAL RECONNAISSANCE AND TECHNICAL SUPPORT CENTER, DEPARTMENT OF THE ARMY, NAVY AND AIR FORCE. Image Interpretation Handbook, 1967.

This reference is a definitive handbook covering the technical aspects of imagery, image and sensory equipment and basic image interpretation. May be considered as a fundamental text in the field and covers the area of imagery interpretation better than any other reference found in the libraries.

RECONNAISSANCE LABORATORY, McDONNELL AIRCRAFT COMPANY. Reconnaissance Reference Manual, 1969. St. Louis, Missouri, 1969.

A reference manual that provides basic information in dealing with sensor equipment and technical data required by the individual involved with a reconnaissance project or program. Although information contained in the manual is keyed primarily to military application, this information will assist the technician in developing aerial reconnaissance projects.

Technical Letter NASA 131, Uses of Conventional Aerial Photography in Urban Areas: Review and Bibliography. USGS for NASA Manned Spacecraft Center, 1968.

A technical paper discussing the use of aerial photography as a tool for looking at the urban scene with an appropriate bibliography. The paper contains a number of references that are pertinent to to the s tudy but have not necessarily been listed in this bibliography, yet have been reviewed for content applicable to this project.

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